How do radioactive atoms “know” when to decay?

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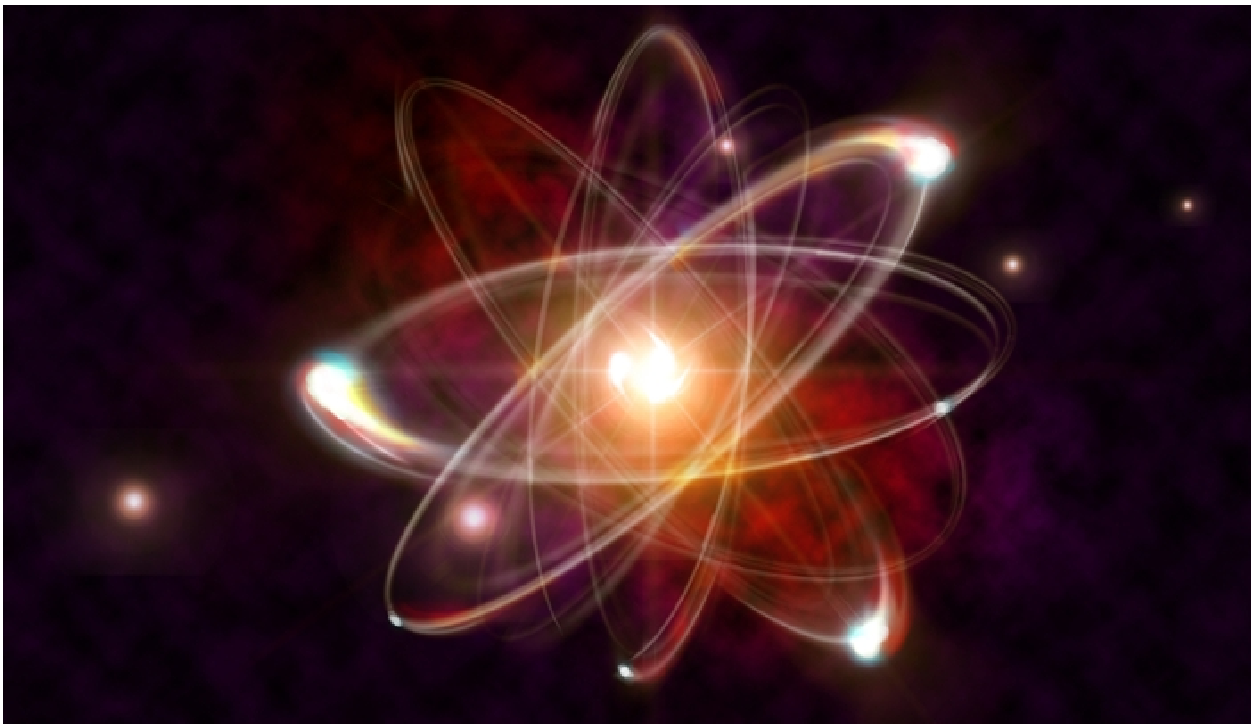

If two atoms of uranium are identical, why will one of them decay now and the other wait until later?Wow! Let me begin by pointing out that the half-life of ^{238}U is about 4.5 billion years. That means that if you have two atoms of ^{238}U, each of them has a 50% chance of decaying in the next 4.5 billion years. If one decayed today, maybe you should buy a lottery ticket.

Radioactive decay is subject to statistical and probabilistic operations, and predictions depend on large populations of nuclei. If you have lots of atoms of ^{238}U, then it is highly likely that in 4.5 billion years you will have close to half as many. But there is no way to predict when a particular (pun intended) nucleus is going to decay.

A nucleus consists of protons and neutrons held together by powerful forces. Certain combinations are more stable than others. It has to do with ratios and “gluons,” but I will try to avoid that part of the explanation. Within one element—and to be careful, let's assume we are talking about one nuclide (or one isotope of one element)—every atom has exactly the same combination of protons and neutrons. It would appear that all the nuclei are identical, but the particles have some combination of “jiggles” inherent in them, like siblings in the back seat of a car.

For a nuclide with a long half-life, most of the time the total jiggling stays inside the limit of the binding force that holds the nucleus together: the nucleus doesn't break apart. Every once in a long while, however, the jiggles might line up or form a resonance that sends the nucleus across the limit of its cohesion, and the nucleus splits.

A nuclide with a shorter half-life (less stable) will violate its binding energy sooner, statistically, than will a nuclide with a longer half-life (more stable). A stable nuclide will never violate its binding energy without the addition of outside forces.

Here's another way to visualize this: Imagine we are walking carrying a pail of water. If the pail is nearly empty, it is stable, and water will not slosh out. If it is full to the brim, it is unstable, and some water is certain to slosh out. In between is a gray area where it may or may not slosh on any given step, and if we aren't paying attention, we won't know when our shoes are going to get wet.

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